UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 587

Joint Contribution from the Bureau of Plant Industry, WM. A. TAYLOR, Chief, and the Bureau of Markets, CHARLES J. BRAND, Chief

Washington, D. C. ▼ September 8, 1917

THE HANDLING AND STORAGE OF APPLES IN THE PACIFIC NORTHWEST

By

H. J. RAMSEY, Pomologist in Charge, Fruit Handling and Storage Investigations; A. W. McKAY, formerly Pomologist; E. L. MARKELL and H. S. BIRD, formerly Scientific Assistants, Office of Horticultural and Pomological Investigations

CONTENTS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1917

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 587

Joint Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief, and the Bureau of
Markets, CHARLES J. BRAND, Chief

Washington, D. C. ▼ September 8, 1917

THE HANDLING AND STORAGE OF APPLES IN THE PACIFIC NORTHWEST.

By H. J. RAMSEY, *Pomologist in Charge, Fruit Handling and Storage Investigations;* A. W. MCKAY, *formerly Pomologist,* and E. L. MARKELL and H. S. BIRD, *formerly Scientific Assistants, Office of Horticultural and Pomological Investigations.*[1]

CONTENTS.

IMPORTANCE OF COLD STORAGE.

According to the census reports of 1910 there were at that time 6,044,918 apple trees of bearing age and 8,643,228 apple trees of nonbearing age in the States of Oregon, Washington, and Idaho. The production in bushels for 1909 is given as 5,262,985, as compared with 1,826,620 bushels 10 years before. In 1913 the apple crop for the four counties of Chelan, Douglas, Okanogan, and Grant, in the State of Washington, was conservatively estimated at 4,328 carloads.

[1] B. B. Pratt, formerly Pomologist; C. W. Mann, Pomologist; K. B. Lewis, formerly Scientific Assistant; George W. Dewey, W. C. Quick, V. W. Ridley, Carl E. Schuster, and E. D. Vosbury, Scientific Assistants in the Office of Horticultural and Pomological Investigations, were actively engaged in the prosecution of these investigations at various times during the period covered by the work.

NOTE.—The fruit and vegetable handling, transportation and storage investigations formerly administered in the Office of Horticultural and Pomological Investigations, Bureau of Plant Industry, are now being prosecuted jointly and cooperatively by the Bureau of Plant Industry and the Bureau of Markets.

This is approximately equal to the 2,672,100 bushels which, according to the census, comprised the entire apple crop of the whole State of Washington in 1909. The production has increased greatly, not only in the counties mentioned but also in Yakima, Spokane, Klickitat, and other counties in Washington, in the Hood River and the Rogue River valleys of Oregon, in eastern Oregon, in the Bitter Root Valley of Montana, and in southwestern Idaho.

The total car-lot shipments of apples from the four States of Oregon, Washington, Idaho, and Montana for the 1915–16 shipping season amounted to approximately 11,166 cars. The total car-lot shipments from these States for the shipping season 1916–17 to March 19, inclusive, amounted to 16,625 cars. The shipments of apples still in storage at that time would increase this amount considerably.

The proportion of each year's crop from these States that is placed in cold storage, either at points of production or in the East, is somewhat difficult of determination. The actual storage holdings necessarily will fluctuate each season with the production, market conditions, and prices. In 1911 something over 225,000 boxes were held in either common or cold storage in the three States first mentioned, as compared with almost 1,000,000 boxes in cold storage in 1914. These figures are indicative of the increasing importance of cold storage in the successful distribution and disposal of the northwestern apple crop. No reliable figures are obtainable regarding the amount of the crop produced in the Northwest and stored in Middle Western and Eastern States during the last few years. Storage facilities in the producing States of the Pacific Northwest are adequate for only a small proportion of the crop. As a considerable proportion of the production consists of late fall and winter varieties, it is obvious that by far the greater portion of the crop must be held in storage for shorter or longer periods either in the producing States or in the East and Middle West. Whether these holdings are the property of the growers, the shippers, or the buyers does not minimize the importance of cold storage in the profitable production and disposal of the northwestern apple crop.

The rapid increase in acreage and production of apples in the Northwestern States has made the wide distribution and profitable marketing of the northwestern apple crop a problem second in importance only to the successful growing of the crop. Cold storage permits a wider and more equitable distribution of apples than is possible when it is not employed, and it extends the season during which apples may be marketed in good condition. Any system which aims at an equitable and economic distribution of the northwestern apple crop must employ cold-storage facilities for the successful preservation for a longer or shorter period of a considerable pro-

portion of the crop. It is therefore of the utmost importance that growers, shippers, warehousemen, and all others concerned in the growing, transportation, or marketing of the apple crop know accurately and definitely (1) what constitutes proper storage facilities, and (2) how the fruit should be handled, both in harvesting and in storage, in order that it may possess when marketed and offered to the consumers the maximum of good condition and quality.

Unless the apple crop can be successfully held in good condition until it reaches the consumer, all other questions and factors are negligible.

FUNCTION OF COLD STORAGE.

For a proper understanding of the behavior of apples in storage it must be kept clearly in mind that the apple, like all fruits, is a living organism and that its life cycle, which begins in the blossom, ends under natural conditions in the death and decay of the fruit. When the fruit is picked from the tree its life processes do not stop. On the contrary, at ordinary temperatures, they continue as rapidly or possibly even more rapidly than before. The function of cold storage is primarily to retard these life processes. Its purpose is also to retard and prevent the germination of spores of fungi which cause the fruit to decay, and to prevent the development of skin blemishes. For this purpose a temperature of between 31° and 32° F. is considered standard for the apple. No temperature, however, which will not seriously injure the fruit by freezing can entirely check its ripening processes or the growth of all fungi which cause decay. It is obvious, therefore, that fruit allowed to become overripe prior to storage can never regain in cold storage the quality and vitality it has lost. Neither can cold storage prevent the final decay of fruit already infected with decay fungi. Since cultural and handling methods largely determine the condition of the fruit when it is stored, the first responsibility for its successful storage lies with the grower and shipper.

EXPERIMENTS OF THE UNITED STATES DEPARTMENT OF AGRICULTURE.

In 1911 the Bureau of Plant Industry began an investigation of factors governing the behavior of northwestern apples in cold storage. Fruit for this purpose was obtained from the Rogue River and Hood River valleys of Oregon, and from the Yakima and Wenatchee sections of Washington. A considerable amount, also, was obtained from other sections in Washington, Idaho, and Montana. Between 500 and 600 boxes of apples were used each season in the experiments, and as each box was picked and packed by a bureau representative or under his immediate supervision, it has

been possible to obtain an exact history of each box stored and also a record of the soil in which it was grown, the condition of the trees, and the cultural methods pursued.

Although the investigations have been comprehensive in scope, so many factors affect the behavior of fruit in storage that the data obtained are still too limited to justify a complete report or definite recommendations with reference to all the factors involved. Certain important practices, however, have been shown to have such a consistent and important bearing on the successful storage of northwestern apples that it is believed advisable to present to the industry at this time the data obtained. No attempt is made to discuss all phases of the problem. The discussion is limited largely to those factors of first importance to the industry on which it has been possible to secure reliable and consistent data over a period of four years.

The data given cover in most cases the seasons 1911–12, 1912–13, 1913–14, and 1914–15.

OUTLINE OF EXPERIMENTS.

(1) A determination of the influence of maturity at time of picking on the keeping quality of the more important varieties grown in the Northwest.

Two pickings from the same trees were made 20 days apart. Frequently an additional pick was made between these two. The first, or immature, pick was made at the beginning of the commercial picking season for the variety. The last, or mature, pick was made 20 days after the first, usually a few days later than the last commercial picks. These lots, comparable in every other respect, were stored immediately at a temperature of between 31° and 32° F. All fruit was stored in Portland, Oreg. Careful inspections were made four times during the winter, beginning in all but the early varieties about the first of January and continuing at intervals approximately six weeks apart. One-fourth of each lot was taken out of storage at each withdrawal, inspected, and held in an ordinary warehouse room for 10 days. It was then inspected again and discarded. The temperature of the fruit during these 10-day periods varied with the season and climatic conditions, but was usually between 50° and 60° F.

(2) A study of the effect of delaying the storage of certain important commercial varieties on their behavior in storage.

For this purpose several boxes of a variety were picked and packed at the same time. Half of each series was placed in cold storage as soon as possible, usually not more than two days from the time of picking; the other half was held two weeks in a grower's or shipper's warehouse before being placed in cold storage. The first lot was

designated "Immediate"; the second, "Delayed." Both lots were stored at 31° to 32° F. and inspected four times during the winter, as in the case of the fruit for the maturity tests.

(3) A determination of the effect of storage temperatures on the keeping quality of several varieties.

For this purpose a certain number of boxes of a variety were secured from the same orchard on the same day, and, as in all the experiments, care was taken to secure as nearly as possible the same type and grade of fruit. Part of each lot was stored immediately at a temperature of 31° to 32° F., and the remainder was also stored immediately at 35° to 36° F. During the seasons of 1912–13, 1913–14, and 1914–15 a limited number of boxes were stored in air-cooled storage houses at Hood River, Oreg., Payette, Idaho, and other points, while comparable lots of the same varieties were held at temperatures of 32° and 35° F. The system of inspection was similar to that followed for the maturity tests.

(4) A study of the keeping quality of different varieties grown and handled under ordinary commercial conditions and stored immediately at 31° to 32° F.

These experiments included nearly all varieties of importance or of promise as storage varieties grown in the three principal sections where work was done. A few varieties were included which, though not widely distributed, seem to possess very good keeping quality.

In addition to the above factors, tests were made of fruit grown on old and young trees, of poorly colored and well-colored fruit, of large and small fruit, of fruit from different soil types, of fruit grown under irrigation and without irrigation, and under cover crop and clean-culture conditions. Other experiments were conducted to determine the effect of dipping fruit in various fungicidal solutions or spraying it with a fungicide after picking as a means of controlling anthracnose decay and apple scab. The effect of water core and dry-rot on the keeping quality of the fruit has also been studied.

TROUBLES AFFECTING APPLES IN STORAGE AND FACTORS IN THEIR CONTROL.

It must not be assumed that the conditions discussed under "Function of cold storage" entirely prevent storage troubles, for at no temperature and under no known condition is it possible to check entirely the physiological changes and ripening processes or the development of fungous decays without destroying the value of the fruit. Few varieties of apples will keep in perfect condition even in cold storage more than a few months, and varieties that will hold in good condition during a long storage season are decidedly valuable.

The troubles that affect northwestern apples in storage may be divided for this discussion into two main groups: (1) Those that

affect only the external appearance of the fruit and are usually designated as skin blemishes and (2) those that injure the flesh of the fruit and are known as decays. Only those of considerable economic importance to the successful storage of northwestern apples will be described. For the sake of convenience in reference the most important factors governing the development and prevention of these various troubles in storage are briefly discussed here. The recommendations made are based on investigational results and also on commercial experience if such experience is available and considered reliable.

SKIN BLEMISHES DEVELOPING IN STORAGE.

The most important skin blemishes are (1) scald, (2) Jonathan spot, (3) soft scald, (4) scab, and (5) bitter-pit; but there are others which are omitted because of their infrequent occurrence and relative economic unimportance in the Pacific Northwest. The importance of skin blemishes can not be overestimated, especially in the marketing of a crop such as the Pacific northwestern apple crop. It is safe to say that more than 25 per cent of all northwestern apples in cold storage are seriously affected by skin blemishes.

FACTORS AFFECTING THE DEVELOPMENT OF SCALD IN STORAGE.

Scald is the most prevalent and most serious of the skin blemishes. It is a browning or blackening of the skin that does not extend into the flesh, but gives the fruit a scalded or baked appearance. Naturally this greatly lessens its commercial value. Plate II illustrates its appearance on Rome Beauty. Commercially scald can not be controlled absolutely, but through proper care in harvesting and storing it can be reduced greatly, and in this connection the following results of the experimental work are important:

(1) Striking differences are found in the susceptibility of varieties to scald. Probably no variety is absolutely immune. Rainier, Northern Spy, Jonathan, Hyde King, Esopus, and Missouri are comparatively so, while the Arkansas, Rome, Wagener, and others often develop an undue amount. Between these extremes come most of the more commonly grown varieties, and the susceptibility of these to scald varies greatly under the different conditions described below.

(2) There is a very appreciable decrease in the amount of scald on apples stored immediately as compared with those stored after a delay of two weeks. The amount of scald on the fruit stored immediately and that delayed two weeks before storage varies greatly with the weather conditions to which the delayed lots are subjected, and in cold weather there may be but little difference.

(3) Apples held at 32° F. scald slightly less than those stored at 35° F. or in common storage.

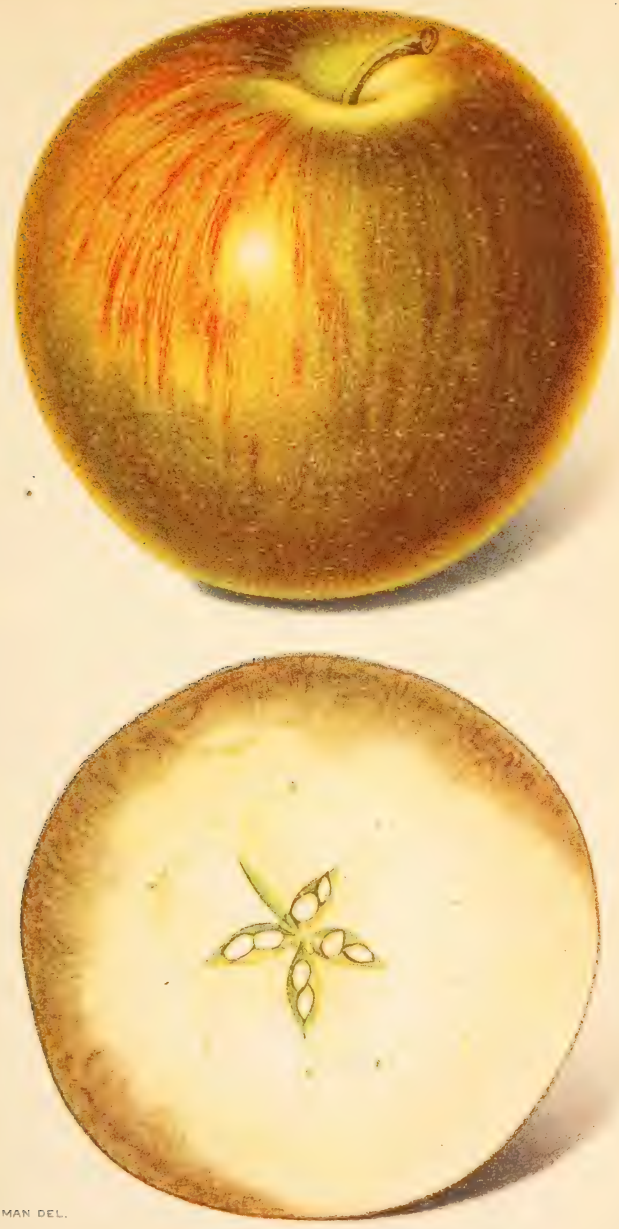
R.C STEADMAN DEL. A. HOEN & CO

ROME BEAUTY APPLES OF NORTHWESTERN PRODUCTION PICKED TOO EARLY FOR HOLDING SATISFACTORILY AT NORMAL STORAGE TEMPERATURE OF 32° F. FOR A SIX-MONTHS' STORAGE PERIOD.

Fruits like the one in the upper figure, with a vivid leaf green area on the shaded side, are too immature for satisfactory storage, even though there is considerable color on the sunny side.

Cross section of a fruit at the same stage of maturity is shown in the lower illustration. The green color is apparent in the flesh.

(*From Yearbook U. S. Dept. of Agriculture, 1916.*)



R.C. STEADMAN DEL. A. HOEN & CO

RESULTS OF HOLDING ROME BEAUTY APPLES, AT THE STAGE OF MATURITY INDICATED IN PLATE I, AT 32° F. FOR SIX MONTHS.

External browning characteristic of fruits picked before the leaf green in the skin had disappeared and held in storage six months is illustrated by the upper figure.

The cross section of the same fruit shows that several layers of cells immediately below the skin, as well as the cells of the skin itself, have ceased to function and have become discolored.

(*From Yearbook U. S. Dept. of Agriculture, 1916.*)

R.C. STEADMAN DEL. A. HOEN & CO.

ROME BEAUTY APPLES OF NORTHWESTERN PRODUCTION HARVESTED AFTER THE LEAF GREEN HAD DISAPPEARED AND THE TRUE YELLOW OF THE NORMAL GROUND COLOR FOR THE VARIETY WAS DISCERNIBLE.

Absence of leaf green, the presence of white, and light yellow in its place—true signs of picking maturity in this variety—are shown in the upper figure.

Cross section of the same fruit from which the green tint in the skin as well as in the flesh has disappeared.

(*From Yearbook U. S. Dept. of Agriculture, 1916.*)

R.C. STEADMAN, DEL. A. HOEN & CO.

ROME BEAUTY APPLES OF THE SAME STAGE OF MATURITY AS THOSE SHOWN IN PLATE III, AFTER HAVING BEEN HELD SIX MONTHS IN COLD STORAGE AT A TEMPERATURE OF 32° F.

No loss of color or discoloration, but the deepening of the yellow in the ground color due to progress of the ripening process, is shown in the upper figure.

The cross section of the fruit, shows no discoloration, but rather an increase in the yellow tint in the flesh, characteristic of the maturing of the variety.

(*From Yearbook U. S. Dept. of Agriculture, 1916.*)

(4) Of even more importance than the comparative susceptibility of varieties is the relation of time of picking to scald. The amount and severity of scald in immaturely picked apples in cold storage are often enormous. As the picking season advances and the fruit matures and colors, the damage decreases, until at near full maturity the scald is comparatively slight. Plates II and IV illustrate the effect of scald on Rome Beauty picked immaturely and at proper maturity after having been out of cold storage for almost three weeks. Plates I and III represent the general appearance of these same lots of apples at the time of picking. In the immaturely picked fruit very severe scald is followed by physiological decay. The intermediate lots have severe scald, but no physiological decay, while the apples picked at maturity show no scald whatever. Table I gives the average percentage of scald in six varieties of apples picked immaturely and at proper maturity upon their withdrawal from storage and also 10 days later. Plate II shows that the scald is confined principally to the uncolored portions on even the immature apples. Severe scald is seldom found on well-colored fruit.

Apples do not usually scald as badly in cold storage as in common or air-cooled storage houses. On withdrawal, however, scald may advance rapidly, and an apple that is perfect on withdrawal from cold storage may in a few days become worthless. Table I, except in the case of Rome Beauty and Arkansas Black, strongly emphasizes this point. It should be noted, however, that the apples picked at proper maturity are comparatively free from scald, both in storage and after withdrawal.

FACTORS AFFECTING THE DEVELOPMENT OF JONATHAN SPOT IN STORAGE.

While affecting Jonathans principally, Jonathan spot is one of the most serious and important skin blemishes, as Jonathans are grown very extensively in all the Northwestern States and this variety is one of the leading commercial sorts in this region. This trouble appears as a small brown or black spot in the skin, usually one-sixteenth to one-quarter of an inch across and more or less rounded. In later stages it may enlarge somewhat and sink slightly. The flesh beneath is seldom injured more than a darkening of the layers of cells next to the skin. When severe, these spots are found scattered thickly over the whole surface of the apple, greatly reducing its market value.

(1) No other varieties are severely affected by Jonathan spot, although it develops occasionally on Esopus, Rome Beauty, and others.

(2) The spots on apples delayed two weeks or more before storage are usually considerably more numerous and severe than on those stored immediately after picking.

(3) While the difference is not as striking as between immediate and delayed storage, there is considerably less Jonathan spot on apples stored at 32° F. than on comparable lots stored at 35° F.

(4) While the data regarding the influence of time of picking on Jonathan spot are rather inconclusive, they indicate that it has little or no influence on its occurrence.

Jonathan spot, like scald, develops much more rapidly after withdrawal than in storage, though the increase is not as marked as in the case of scald. It is an interesting fact that some lots of Jonathans are severely affected by Jonathan spot, while others apparently identical in every other way are entirely free or nearly so.

FACTORS AFFECTING THE DEVELOPMENT OF SOFT SCALD IN STORAGE.

Soft scald varies greatly in importance and severity in different years. None of the experiments so far has led to any definite conclusions. Jonathan, Blue Pearmain, and Wealthy seem to be particularly susceptible and are often rendered worthless in storage because of soft scald. Soft scald varies from small spots an eighth of an inch or less across to large areas that sometimes include the whole surface of the apple. The scalded area is light brown, becomes markedly sunken, is distinctly margined, and the flesh beneath turns brown and softens somewhat. In severe cases this condition may extend well into the flesh. The cause of soft scald is not definitely known, and there seems at present to be no way of preventing it.

As with the Jonathan spot, in one lot nearly every apple may be affected, while in others apparently no soft scald is found. Soft scald increases rapidly after withdrawal from cold storage, and fruit that is slightly affected when withdrawn may soon become worthless. There is usually more soft scald in apples delayed before storage than in apples stored immediately. On Jonathans the severity of soft scald increases rapidly after withdrawal from cold storage, and fruit severe on apples known to have been cooled to temperatures below 32° F. There are also indications that the trouble is related to box bruising or bruising resulting from very tight packing.

FACTORS AFFECTING THE DEVELOPMENT OF SCAB IN STORAGE.

Scab is another serious skin blemish, differing from the forms previously mentioned in that it is a fungous disease and can be quite effectively controlled by proper spraying while the fruit is on the tree. This serious trouble often develops at a temperature of 32° F. on fruit apparently free from scab when stored. The orchard treatment of the crop must be such as to insure a product free from scab for storage, for it can not be controlled by spraying or by dipping in a fungicidal solution after the apples are picked. Preventive measures must be taken by the grower and can be taken by him alone. This again emphasizes the importance of good orchard sanitation, not only to maintain the vigor and health of the trees but

also to preserve the quality and appearance of the fruit in storage. Because of its nature, scab is more conspicuous on yellow and green varieties than on red ones. There are few, if any, varieties that are entirely immune from the disease. As is the case with all fungous troubles affecting apples in storage, immediate storage and prompt cooling are of some value in reducing the injury, but the main reliance for its control must necessarily depend on proper spraying.[1]

FACTORS AFFECTING THE DEVELOPMENT OF BITTER-PIT IN STORAGE.

Occasionally bitter-pit causes serious losses in storage and in the Pacific Northwest is frequently confused with fruit-spot and stigmonose. The fungous fruit-spot of the East is probably not present in the Pacific Northwest. Stigmonose, however, is common in this section and is very hard to distinguish from bitter-pit. The presence of a minute puncture in the skin over the affected area is sometimes the means of identifying stigmonose. The spots of the bitter-pit are usually visible on the surface as dark, slightly sunken areas one-eighth to one-third of an inch in diameter.

Many affected fruits are sorted out at packing time, but as they are hard to recognize and the pits often develop in storage, the trouble is not eliminated thereby. No effective methods of control have been suggested, as up to the present time the cause is not definitely known. It does not appear to be due to any organism, but is said to be caused by an unbalanced condition existing in the tree or parts of the tree that prevents the proper development of the fruit. Some varieties, such as Baldwin, Yellow Newtown, and others, appear to be particularly susceptible to the disease. It would not seem advisable to store apples for first-class trade from orchards where a high percentage of the fruit is thus affected. The disease mars the attractiveness of the fruit and renders it unfit for other than culinary use, but it does not appear seriously to affect its keeping qualities.

TYPES OF DECAYS DEVELOPING IN STORAGE.

The decays affecting apples in cold storage may be divided into two general classes: (1) Physiological or natural death decay of fruit which has reached the end of its life; (2) fungous or bacterial decays or those caused by the growth of some organism in the tissue of the fruit. These again may be divided into two general classes: (1) Parasitic fungi, those that have the power of penetrating the sound unbroken skin of the fruit, and (2) saprophytic fungi, those that ordinarily do not penetrate the skin unless it is injured, broken, or in a weakened condition.

[1] The various State experiment stations and the United States Department of Agriculture give concise directions for effective methods of scab control. Any failure properly to control scab under normal conditions is usually because the grower did not spray thoroughly or at the proper time.

FACTORS AFFECTING THE DEVELOPMENT OF PHYSIOLOGICAL DECAY IN STORAGE.

Physiological or old-age decay is shown in Plates II and VII. All fruit, if not otherwise destroyed, eventually decays physiologically when it has passed through certain natural changes. It is essential to successful storage that these changes or ripening processes be retarded, as this is the fundamental principle upon which the cold storage of all fruits is based.

(1) *Soundness of fruit.*—One of the most important considerations in the control of physiological decay in storage is the selection of sound fruit of naturally long-keeping varieties. Such varieties as Rainier, Winesap, Arkansas Black, and Yellow Newton will, as is generally known, keep in good condition much longer than Grimes, Jonathan, and McIntosh.

(2) *Immediate storage compared with delayed storage.*—The promptness with which the fruit is stored and cooled after it is picked is the most important single factor in retarding physiological decay. After the apples are picked, a few days in the orchard or packing houses may greatly shorten their cold-storage life, especially if the weather is hot and the fruit is left in a warm place. Plates VI and VII show the condition of Jonathan apples as regards ripeness and maturity when stored immediately after picking and when delayed for two weeks before storage. There was no difference in treatment or handling except for the delay of two weeks in the grower's packing house before storing in the case of the apples shown in Plate VII. The life in cold storage of the immediately stored apples illustrated in Plate VI was at least a month longer than that of the delayed, Plate VII. There are few factors of greater importance than prompt cooling and storage in successfully prolonging the storage life of apples.

(3) *Storage at 32° and 35° F.*—In principle and results the storage of apples at a temperature of 35° F. is comparable with delayed storage, i. e., the slower the cooling and the higher the temperature at which the apples are held, the more rapidly will they ripen and death decay set in. Table IV gives the percentage of decay in comparable lots of apples stored at the two temperatures.

(4) *Apples picked while immature compared with those picked at maturity.*—Despite the fact that death decay is primarily the result of the completion of the life processes, it does not follow that apples picked previous to maturity will keep longer than fruit picked at maturity. Apples picked when immature, as previously noted, are usually very susceptible to scald. Severe scald is in turn very frequently followed by a peculiar type of physiological decay of the flesh directly beneath the scalded area. Plate II shows very clearly this type of physiological decay on a Rome Beauty.

E. I. SCHUTT A. HOEN & CO.

NORTHWESTERN-GROWN ESOPUS PICKED TOO LATE FOR HOLDING SATISFACTORILY AT NORMAL STORAGE TEMPERATURE OF 32° F. FOR A THREE AND ONE-HALF MONTHS' PERIOD.

Picking at over-maturity is fully as serious as picking immaturely. Most serious storage losses in varieties like Esopus, King David, and Jonathan, are due to over-maturity at time of harvesting.

E. I. SCHUTT A. HOEN & CO.

NORTHWESTERN-GROWN JONATHANS IMMEDIATELY AFTER HARVESTING, WHEN WITHDRAWN FROM THREE MONTHS' STORAGE AT A TEMPERATURE OF 32° F.

Fruits like the above picked at the same time as the apple shown in Plate VII are still in prime condition and were held in storage for a month longer in perfect condition.

E. I. SCHUTT A. HOEN & CO.

NORTHWESTERN-GROWN JONATHANS DELAYED SEVERAL DAYS BEFORE BEING PLACED IN STORAGE WHEN WITHDRAWN FROM THREE MONTHS' STORAGE AT 32° F.

Fruits like the above, picked at the same time as the apple shown in Plate VI, are obviously too ripe even for immediate consumption, and entirely worthless for further storage. The delay of a few days prior to storage lessens oftentimes the length of time during which they can be held in storage by one or two months and seriously affects their flavor, quality, appearance, and market value.

(5) *Overmaturity.*—On the other hand, overmaturity is usually more disastrous than immaturity. It is practically the same as excessive delay, discussed under "Immediate versus delayed storage." The fruit has received all of its sustenance from the tree, and the ripening and life processes continue rapidly, especially in fruit exposed to the sun. Overmaturity is often responsible for the early decay of Esopus (Spitzenberg), King David, Jonathan, and others. During the season of 1914–15 more apples from various sections of the Northwest decayed early in the season from this cause than from any other. Table II gives a comparison of decay in Esopus picked at maturity and when overmature. The effect of overmaturity is well illustrated in Plate V.

(6) *Water-core.*—The cause of water-core is as yet unknown. Many theories are offered, but none seems satisfactory. Water-core is often largely responsible for early physiological decay. In storing such varieties as King David and Tompkins King it is advisable to be certain that little or no water-core is present, as water-cored fruit of these varieties usually decays early. In apples of firm flesh, such as Winesap and Yellow Newtown, in which the water-cored area is normally much smaller, the effect is not so severe. However, even in these varieties water-cored fruit should ordinarily not be held as long as that which is not affected. At best its storage is somewhat of a risk.

(7) *Bruising.*—It is at the bruised or weakened part of an apple that physiological decay first gets a start. Severe bruising not only injures the appearance but shortens the life of the fruit.

FACTORS AFFECTING THE DEVELOPMENT OF PARASITIC FUNGI IN STORAGE.

Of the parasitic fungi, northwestern anthracnose (*Gloeosporium malicorticis* Cordley) is the only one at present of any great commercial importance. It may cause the decay of fruit in storage that is apparently sound at packing time, spreading rapidly from apple to apple and occasionally affecting all the fruit in a box.

Northwestern anthracnose begins as a minute tan-colored spot in the skin that spreads rapidly in warm, moist conditions over a large area and extends into the flesh. Usually several spots appear on each affected apple. They are round or oval and often grow together as they increase in size. Both skin and flesh are light brown and are nearly odorless and tasteless. Occasionally small pustules may be seen on the surface. At a late stage white spore masses on the surface are not uncommon and the skin may break. Immediate storage is of some value in delaying the period of development. Time of picking, color, and careful handling play little or no part in control. Neither does dipping the fruit in a copper-sulphate solution before

packing prevent attack. The decay spreads very rapidly after withdrawal from storage. The control of northwestern anthracnose must necessarily lie in proper orchard sanitation practices.[1]

FACTORS AFFECTING THE DEVELOPMENT OF SAPROPHYTIC FUNGI IN STORAGE.

Blue mold stands out above all other fungi of this class in importance. Although it is the most common fungous enemy of northwestern apples in storage, it is fortunately one that can be controlled almost entirely. In the field and in storage this fungus gains entrance through any broken or weakened portion of the skin. It is easily recognized by its distinctive odor, and in its later stages by an abundance of small tufts and masses of green spores on the infected areas.

(1) The resistance of varieties to blue mold bears a direct relation to toughness of skin and length of stem. Varieties with tender skins and long stems with which other apples in the box may be punctured are likely to be most susceptible to blue mold.

(2) The higher the temperature, the faster the development of the fungus. For this reason, immediate storage is better than delayed, and 32° F. is better than 35° F.

(3) Because of the weakening effect of severe scald, immature or poorly colored fruit is occasionally more susceptible to blue mold than well-colored apples.

(4) Careful handling is the fundamental factor in the control of blue mold. It is seldom that an infection can not be traced to some injury of the apple that could have been prevented.

RESULTS OF THE EXPERIMENTS.

The importance of good orchard sanitation in preventing the development of storage rots and skin blemishes has already been pointed out. As a matter of fact, the grower's responsibility goes back even farther. He more than any other single individual influences the keeping quality of his fruit in storage, since by his orchard practices he is directly responsible for its quality, vitality, and freedom from disease. Only gross negligence on the part of the shipper or warehouseman can nullify the effect of good cultural and sanitary orchard practices. On the other hand, if fruit is poorly grown or is diseased the utmost care on the part of the warehouseman can not prevent the premature development of storage troubles.

Assuming, then, that one has well-grown and well-developed apples, free from disease, the important steps in the successful storage of this fruit are as follows:

[1] Information regarding pruning and spraying practices for the control of northwestern anthracnose can be obtained from the experiment stations in the various States.

(1) Picking at a proper maturity.
(2) Care in all handling operations.
(3) Prompt storage.
(4) A proper storage temperature.

MATURITY AT THE TIME OF PICKING.

Table I gives the average percentage of serious storage troubles found in Rome Beauty, Winesap, Yellow Newtown, Stayman Winesap, Ortley, and Arkansas Black when picked at and somewhat before full maturity. These include "bad scald," the term used to designate scald that is serious enough to detract from the commercial value of the fruit, and physiological and fungous decays. Other storage troubles are noted as they appear in the various lots. The results given for Yellow Newtown and Rome Beauty are an average of the data obtained during the four seasons the work has been carried on. The Winesap results are an average of three seasons' experiments, 1912–13, 1913–14, and 1914–15. The Stayman Winesap and Ortley data cover but two seasons, while the data for Arkansas Black are for one year, but include several lots.

No definite statement can be made regarding the commercial picking dates of a variety. Yellow Newtown, Rome Beauty, and Winesap may usually be harvested any time between the latter part of September and first of November, depending upon seasonal conditions and the degree of maturity desired. Great variation in the time at which apples mature is also caused by the age of the trees, the soil, cultural conditions, elevation, and the site of the orchard. In general, the immature pickings of these varieties were made during the last two weeks of September and the mature pickings from October 2 to October 20.

The first three sections of Table I and Plates I and II show the injurious effect of immature picking clearly enough to require little discussion. In Rome Beauty (Table I) at the third withdrawal from storage, March 31 to April 2, the immature fruit developed more than 48 times as much bad scald in storage as the mature fruit. Even at the last withdrawal, May 4 to 11, there was 17 times as much bad scald in the early as in the mature picking. These figures, it must be remembered, are not the results of a single experiment, but the average of several experiments covering a period of four years. The results with Winesap (Table I) are equally striking. It is reliably estimated that several thousand dollars are lost to the industry each year by premature pickings of these two varieties alone. As the first pickings were made no earlier than a considerable portion of the same varieties are picked commercially, the necessity for strict attention to this point is plainly evident.

TABLE I.—*Comparison of mature and immature apples with regard to the percentage of bad scald and decay at withdrawal from storage and with regard also to the total percentage after a holding period of 10 days under market conditions, the time in storage at first withdrawal being three to three and one-half months.*

ROME BEAUTY (FOUR-YEAR AVERAGE).

Condition.	First withdrawal, Jan. 8 to 12.		Second withdrawal, Feb. 16 to 19.		Third withdrawal, Mar. 31 to Apr. 2.		Fourth withdrawal, May 4 to 11.	
	Mature.	Immature.	Mature.	Immature.	Mature.	Immature.	Mature.	Immature.
Bad scald:								
At withdrawal...	0	0	0	20.5	1.0	48.9	3.5	58.9
10 days later.....	1.7	49.9	5.4	70.5	10.4	81.5	17.8	81.6
Decay:								
At withdrawal...	0	.1	0	0	0	.2	.1	.4
10 days later	.2	.6	.2	0	1.6	9.8	2.7	18.0

WINESAP (THREE-YEAR AVERAGE).

Bad scald:								
At withdrawal...	0	0.1	0	7.6	0	15.5	0.6	15.5
10 days later.....	0	9.6	.2	13.9	3.3	25.7	11.3	33.5
Decay:								
At withdrawal...	0	0	.3	.3	.5	.3	.5	.6
10 days later.....	.1	.1	.3	.3	.8	.5	.7	.7

YELLOW NEWTOWN (FOUR-YEAR AVERAGE).

Bad scald:								
At withdrawal...	0	0	0	0	0	0.5	2.1	0
10 days later.....	0	1.8	2.1	1.3	1.5	1.0	14.8	19.8
Decay:								
At withdrawal...	0	0	0	0	0	0	0	0
10 days later.....	0	0	0	.2	0	0	2.0	2.6

STAYMAN WINESAP (TWO-YEAR AVERAGE).

Condition.	First withdrawal, Jan. 14 to 18.		Second withdrawal, Feb. 25 to 28.		Third withdrawal, Mar. 31 to Apr. 2.		Fourth withdrawal, May 7 to 11.	
	Mature.	Immature.	Mature.	Immature.	Mature.	Immature.	Mature.	Immature.
Bad scald:								
At withdrawal...	0	1.1	8.9	84.3	39.4	86.1	41.0	91.8
10 days later.....	11.4	87.5	36.6	92.8	51.6	90.2	65.1	92.6

ORTLEY (TWO-YEAR AVERAGE).

Bad scald:								
At withdrawal...	0	0	4.0	6.6	9.9	30.4	.....	.....
10 days later.....	3.1	3.7	17.4	30.0	40.1	48.1	.....	.....
Decay:								
At withdrawal...	0	0	2.0	1.1	7.0	7.0	.....	.....
10 days later.....	1.1	0	3.5	4.0	20.7	25.5	.....	.....

ARKANSAS BLACK (RESULTS OF ONE YEAR WITH LOTS FROM SEVERAL SECTIONS).

Bad scald:								
At withdrawal...	0	0	0	0	0	0	0	1.2
10 days later.....	0	0	0	6.0	0	7.7	1.3	52.8
Decay:								
At withdrawal...	0	0	0	0	0	0	.6	0
10 days later.....	0	0	0	0	0	.6	4.2	10.8

NOTE.—Slight inconsistencies such as those noted above are not uncommon where the results of only one or two years' work are available. It is because of this fact that except where substantiated by other evidence it is not safe to generalize on only one or two years' data.

In Rome Beauty, Winesap, and Yellow Newtown scald causes more serious injury than decay. It has been found that all varieties susceptible to scald are attacked much more quickly and seriously when picked prematurely than when picked at full maturity, as shown in Plates II and IV. The most practical and efficacious preventive of this trouble, therefore, is picking the fruit at proper maturity. No other factor has such an important bearing on the amount of scald which develops in storage. The general appearance of scald on Rome Beauty is well illustrated in Plate II. It is probable that the cells which make up the skin of the immature fruit are undeveloped and weak, and therefore break down quickly in storage. In this connection it is important to note that physiological decay, such as is shown in Plate II, often follows severe scald. In the case of red varieties, allowing the fruit to remain on the tree until proper maturity is reached permits the green area to become partially or completely colored (Pl. III) and consequently practically immune from scald. It also allows the whole surface of one naturally green or yellow in color to become mature enough to resist the trouble.

As far as physiological and fungous decays are concerned, the differences shown in the table are not so striking. Very serious scald, however, finally weakens the skin of the fruit so that complete physiological decay results or a point of entrance is offered to decay fungi. This explains the very serious decay in the immature Rome Beauty at the third and fourth withdrawals. It will be observed that very little of this decay developed at 32° F., but after withdrawal to the warmer outside temperatures the immature fruit, weakened by bad scald, went down very rapidly, while a comparatively small amount of decay developed in the fruit which was mature when picked.

Winesap, usually considered a longer keeping variety than Rome Beauty, was apparently not seriously weakened by scald, as very little decay developed either in storage or after withdrawal. Yellow Newtown (Table I) shows considerably more decay in the immature lots than in the mature at the last withdrawal, though the difference in the percentage of scald is much less pronounced than in the first two varieties. These differences, however, were greater than the figures indicated. The individual apples in the immature lots were, as a rule, more seriously affected than those in the mature lots, and consequently more weakened and more susceptible to decay.

WHEN IS AN APPLE AT PROPER MATURITY?

Regarding the stage of maturity at which apples should be picked it is difficult to give directions which will apply to all conditions and seasons. Proper maturity certainly does not mean eating

ripe, as in nearly every case an eating-ripe apple is overmature for storage. The individual growers should study their own fruit and their own conditions and whenever possible should make experiments to determine the stage of maturity at which the varieties they grow hold best in storage. The color of the seeds gives some indication, yet in spite of many opinions to the contrary it is an unreliable index to the maturity of the fruit. Many factors may cause the color of the seeds to vary without affecting materially the time at which the fruit reaches full maturity. The blush or red color of the apple taken by itself also is unreliable. Both of these factors should be taken into consideration, however. Perhaps the most reliable single indication is the "ground" color of the fruit; that is, the color which underlies the red color or blush. The "ground" color, which is green when the fruit is immature, begins to whiten or yellow slightly as it approaches full maturity. Plates I and III illustrate very well immature and mature Rome Beauty apples at time of picking. As a rule, in a mature apple the green color should be largely replaced by a white or light-yellow color. A dark yellow, on the other hand, usually indicates overmaturity. Allowances, of course, should be made for the natural color of the variety, the amount of exposure to sunlight, etc. Experience will enable a grower to give the proper weight to each one of these factors and properly to coordinate them.

EFFECT OF OVERMATURITY.

It may be stated that certain varieties, of which Rome Beauty and Winesap are examples, are, as a rule, picked too early to keep in the best condition in storage. Some other varieties, however, such as Jonathan and Esopus (Spitzenberg), sometimes are left on the trees later than is advisable. It should be understood clearly that maturity does not mean overmaturity, and that overmaturity may cause losses as serious, or even more serious, than those due to immaturity. As might be expected, the storage troubles resulting in this case are physiological and fungous decays. An apple allowed to remain on the tree until overripe is much farther advanced in its life processes than it is if picked at proper maturity and breaks down just so much faster in storage. The final breakdown may be due either to premature physiological decay or to a fungous rot which the weakened fruit can not resist. The complete destruction of the fruit follows in either case. Trouble of the kind in Esopus (Spitzenberg) is shown in Table II, the last picking of which was made when the fruit was overmature. Plate V illustrates the condition after removal from storage of Esopus apples picked when overmature.

TABLE II.—*Comparison of mature and overmature Esopus (Spitzenberg) apples with regard to the percentage of physiological and fungous decay at withdrawal from storage and with regard also to the percentage of decay after a 10-day holding period under market conditions, one experiment, 1913–14.*

[The first pick was made September 25 and stored September 26, 1913; the second pick was made October 10 and stored October 11, 1913.]

Condition.	First withdrawal, Jan. 12, 1914.		Second withdrawal, Feb. 19, 1914.		Third withdrawal, Apr. 1, 1914.		Fourth withdrawal, May 4, 1914.	
	First pick.	Second pick.	First pick.	Second pick.	First pick.	Second pick.	First pick.	Second pick.
Decay:								
At withdrawal...	0.0	2.3	0.9	9.1	1.3	4.0	2.7	14.0
10 days later.....	1.3	2.3	1.3	25.0	2.7	26.0	6.7	36.0

At the second withdrawal, February 19, which is somewhat later than the usual commercial storage limit for this variety, the first picking was free from decay or other storage troubles, while the later picking had developed 9.1 per cent decay. After being held outside for 10 days, a period approximating the usual length of time from storage to consumption, the decay in the late picking increased to 25 per cent. The first picking developed only 1.3 per cent in the same period. In other words, one lot was in prime market condition and the other in very poor condition. The later inspections are well past the commercial limit for the variety, and the decay is correspondingly heavier, though still consistently less in the first picking. The fact that less decay was found in the second picking at the third withdrawal than at the second withdrawal over a month before is an inconsistency which sometimes arises where only one series of observations has been made. Inconsistencies of this nature are largely eliminated when the results of several experiments are averaged.

Although decidedly inferior in keeping quality, the second picking was strikingly superior in color. This factor, however, did not add to the value of the fruit sufficiently to counterbalance the difference in amount of decay. Possibly a picking made between the two would be superior to either and might have possessed the keeping quality of the first picking with a large portion of the color of the second.

CAREFUL HANDLING.

No special investigations have been conducted with the apples of the Northwest relative to the effect of careful handling in lessening injuries which render the fruit liable to attacks of blue mold and other saprophytic fungi. Extensive experiments by the Bureau of Plant Industry, however, have demonstrated conclusively that care

in all handling operations is of primary importance in insuring sound fruit, whether in storage or in transit. The results of these investigations, which have covered many classes of fruit, have been published as bulletins of the Department of Agriculture,[1] and it is unnecessary to discuss this subject in any detail here.

The fact that blue mold causes serious storage decay in apples, especially those that have been carelessly and roughly handled, is of special interest to the apple growers of the Northwest. As has been previously stated, the fungus causing this trouble can not affect uninjured, healthy fruit, and decay due to this cause can be largely prevented by reasonable care in the harvesting and handling operations. Common sources of injury under commercial handling methods are very numerous. Finger-nail scratches by the pickers or packers, allowing sand and gravel to accumulate in the bottom of the boxes or nails and splinters to project from the bottom and sides, dropping the fruit carelessly into the picking boxes, careless stacking of the filled picking boxes in the field or on the wagon, and rough handling in loading the fruit and hauling it over rough roads on springless wagons are all sources of injury. In the packing house or shed the fruit is frequently dumped roughly into the packing bins and may be injured further by an improperly constructed or adjusted mechanical sizer. Injuries caused by stem punctures and cover bruises, which may be due to improper packing, or carelessness on the part of the pressman, are of very frequent occurrence. Many of the injuries caused in this way may be very small. None of them, however, is insignificant. A microscopic break in the skin of an apple is sufficiently large to afford entrance to the decay fungi, and bruises which are not noticeable when the fruit is packed may cause premature physiological decay in storage.

Careful handling includes careful grading. All poorly developed, imperfect, and injured fruit should be eliminated from the storage lots.

IMMEDIATE VERSUS DELAYED STORAGE.

When an apple is removed from the tree, growth ceases, but the life processes which result in ripening continue more or less rapidly, the rapidity depending on the temperature at which the fruit is held. Under high temperatures ripening goes on very rapidly and the fruit approaches the end of its natural life much more quickly than when these processes are retarded by low temperatures.

Delay before storage usually involves the exposure of the fruit for a longer or shorter period to a temperature decidedly higher than that

[1] Bulletins of the United States Department of Agriculture No. 63, Factors Governing the Successful Shipment of Oranges from Florida; No. 274, Factors Governing the Successful Shipment of Red Raspberries from the Puyallup Valley; No. 331, The Handling and Shipping of Fresh Cherries and Prunes from the Willamette Valley.

of a cold-storage room. The rapidity of ripening is therefore much greater, and the end of its life, even if it is subsequently placed in cold storage, comes just so much sooner than it otherwise would. It may be expected then that fruit treated in this way will show a much higher percentage of physiological and fungous decay in storage than that stored immediately after picking and that it will be more seriously affected by skin blemishes.

In all the experiments of this nature, the delayed lots were held two weeks in growers' or shippers' warehouses at a temperature only slightly lower than that of the outside air. In every other respect each delayed lot was comparable with the corresponding "immediate." The data given do not fully represent the differences between the lots. The immediately stored fruit was always brighter, less yellow, and usually firmer than the delayed. Plates VI and VII illustrate the differences in ripeness upon withdrawal of Jonathans stored immediately and those delayed two weeks. The immediately stored lots, from which the apples in the illustrations were taken, held in storage in good condition one month longer than the comparable delayed apples. Toward the end of the storage period the delayed fruit frequently showed considerable shriveling, while the shriveling in the same fruit stored immediately was slight or entirely absent. Table III shows that there was consistently more bad scald and decay in the fruit delayed for two weeks than in that stored immediately. Data for the most important varieties represented in these experiments are given in the table. This fruit usually was picked at the height of the commercial season for the variety. Definite dates would only be misleading, because, as has been said, these vary greatly with conditions.

The effect of delayed storage on the keeping quality of the fruit varies greatly with different varieties and with climatic and seasonal conditions. If warm weather and high humidity are experienced during the delay period, the ripening of the fruit goes on very rapidly, and, in addition, conditions are then most favorable for the growth and development of fungi causing decay and skin blemishes. On the contrary, if the weather is cool and dry, ripening is comparatively slow and the development of fungous troubles is retarded. Under these conditions, the delay may be only slightly injurious. The table given shows the results with fruit held under varying conditions of temperature and humidity, and the data are the averages of the differences that may be expected to develop between immediately stored and delayed fruit. They do not show the maximum amount of storage troubles that will result from delay during warm and humid weather.

TABLE III.—*Comparison of immediate and delayed storage of apples with regard to the percentage of bad scald and decay at withdrawal from storage and with regard also to the total percentage after a holding period of 10 days under market conditions, the time in storage at first withdrawal being three to three and one-half months.*

YELLOW NEWTOWN (THREE-YEAR AVERAGE).

Condition.	First withdrawal, Jan. 8 to 13.		Second withdrawal, Feb. 19 to 21.		Third withdrawal, Mar. 27 to Apr. 3.		Fourth withdrawal, May 6 to 13.	
	Immediate.	Delayed.	Immediate.	Delayed.	Immediate.	Delayed.	Immediate.	Delayed.
Bad scald:								
At withdrawal	0	1.2	1.8	6.4	6.3	23.5	11.0	30.2
10 days later	2.6	19.5	9.8	33.3	27.6	43.6	28.2	56.5
Decay:								
At withdrawal	.4	0	.3	0	.9	.9	.8	1.9
10 days later	.6	.6	.8	.4	2.9	5.4	5.2	14.4

WINESAP (FOUR-YEAR AVERAGE).

Bad scald:								
At withdrawal	0	0	0	0.2	1.2	2.3	0.4	1.7
10 days later	0	1.3	.8	.9	3.8	6.4	7.3	8.8
Decay:								
At withdrawal	0	.2	0	0	.4	1.0	.1	.4
10 days later	.4	.4	0	0	.7	1.6	.8	1.3

ROME BEAUTY (FOUR-YEAR AVERAGE).

Condition.	First withdrawal, Jan. 9 to 12.		Second withdrawal, Feb. 16 to 29.		Third withdrawal, Mar. 27 to Apr. 2.		Fourth withdrawal, May 5 to 14.	
	Immediate.	Delayed.	Immediate.	Delayed.	Immediate.	Delayed.	Immediate.	Delayed.
Bad scald:								
At withdrawal	0	0	1.8	3.0	11.3	21.9	22.2	27.9
10 days later	12.6	18.3	23.7	40.0	28.4	49.6	42.5	67.1
Decay:								
At withdrawal	.3	.6	.5	2.6	1.0	4.4	1.7	3.7
10 days later	1.2	2.8	1.2	5.8	3.3	13.4	13.6	21.5

ESOPUS (FOUR-YEAR AVERAGE).

Bad scald:								
At withdrawal	0	0	0	0	0.4	0	0	0
10 days later	0	0	0	0	1.7	.5	1.6	2.8
Decay:								
At withdrawal	.1	2.4	2.6	4.3	6.4	9.2	8.9	12.1
10 days later	1.4	6.5	6.0	10.0	11.3	22.1	23.4	28.4

JONATHAN (FOUR-YEAR AVERAGE).

Bad scald:								
At withdrawal	0	4.0	0.1	6.7	8.5	21.5	17.9	33.8
10 days later	1.0	7.3	8.4	20.0	14.7	35.8	27.0	46.4
Decay:								
At withdrawal	0	.3	4.6	10.3	6.8	13.1	7.8	13.0
10 days later	1.2	1.2	10.1	12.7	12.2	17.5	12.0	17.0

In the Pacific Northwest, as in all apple sections of the United States, the fruit after picking is held frequently two weeks or longer in an open warehouse, or even in the orchard, before it is

shipped or stored. The delay period selected for the experimental lots is not excessively long, therefore, and is entirely representative of delay under commercial conditions. Much of the delay of commercially handled fruit is unavoidable, but a great deal of it could be eliminated by a reasonable modification of orchard and packing-house methods. When it is impossible for a grower to store or ship his fruit promptly after it is picked, he should hold it at the lowest temperature available. A common storage room in which the fruit temperatures may be reduced by the cooler night air, and which is sufficiently insulated to maintain this lower temperature during the day, is a valuable adjunct to any orchard and is becoming increasingly necessary in handling the apple crop. In brief, the grower should keep clearly in mind the fact that the higher the temperature at which his fruit is held after it is picked, the more rapid will be its ripening and deterioration.

With the longer keeping varieties, such as Winesap, the effect of a delay prior to storage is not as marked as with the earlier, shorter lived ones, and may not be noticeable during the first part of the storage season. As the fruit advances in its storage life, the differences between immediately stored and delayed lots become greater, and the injurious effect of the delay becomes apparent. With the Jonathan, on the other hand, consistent and striking differences usually are noticeable before the fruit has been in storage two months. The excessive amount of Jonathan spot, or "arsenic spot," following delayed storage, is especially pronounced in this variety, and it is very evident that prompt storage is an important factor in retarding the development of this trouble.

THE EFFECT OF STORAGE TEMPERATURES.

For successful long storage northwestern-grown apples should be held at the lowest temperature possible without danger of freezing. A temperature between 31° and 32° F. is accepted generally as the most favorable for successful storage. Although the exact freezing point of apples has not been definitely determined and may vary with different varieties and conditions of growth, etc., it is known to be 2 or 3 degrees lower than this. Thirty-two degrees F. is the freezing point of distilled water, and a somewhat lower temperature is required to freeze a concentrated fruit juice. Unless a good continuous air circulation is assured in the storage room, however, 31° F. should be considered the lowest limit at which the temperature can be held with safety. The danger from pockets of colder air at the floor, the refrigeration pipes, or cold-air ducts renders it inadvisable to allow the temperature to drop lower unless a thorough and constant air circulation is assured.

In all the experiments the fruit held at 32° F. was in better condition and could be held through a longer storage period than that stored at a temperature ranging from 35° to 36° F. The practical effect of this higher temperature was the same as that of delay before storage. The life activities of the fruit stored at 35° F. advanced with greater rapidity than at 32° F. Consequently at all withdrawals fruit stored at 35° F. was found to be duller, yellower, and riper than the fruit held at 32° F. This was especially true at the later withdrawals. In addition, a higher percentage of scald and storage decays developed at 35° F.

Table IV shows the percentages of decay found in three of the varieties represented in these experiments. Each section of the table gives an average of all experiments conducted during three shipping seasons, 1912–13, 1913–14, and 1914–15. All the fruit was picked at the height of the commercial picking season for each variety, and the lots held at 32° F., as well as those at 35° F., were stored as soon as possible after picking, generally not more than two days later.

TABLE IV.—*Comparison of apples stored at 32° and 35° F. with regard to the percentage of decay at withdrawal from storage and with regard also to the total percentage after holding 10 days under market conditions, 3-year average, the time in storage at first withdrawal being three to three and one-half months.*

ESOPUS (SPITZENBERG).

Condition.	First withdrawal, Jan. 7 to 13.		Second withdrawal, Feb. 17 to 21.		Third withdrawal, Mar. 31 to Apr. 3.		Fourth withdrawal, May 5.	
	32°	35°	32°	35°	32°	35°	32°	35°
Decay:								
At withdrawal...	0	0.7	0.6	4.8	10.1	13.9	12.4	15.1
Ten days later...	.7	8.4	2.9	11.9	12.4	17.4	21.4	26.4

ROME BEAUTY.

Condition.	First withdrawal, Jan. 12 to 16.		Second withdrawal, Feb. 20 to 21.		Third withdrawal, Apr. 2.		Fourth withdrawal, May 5.	
	32°	35°	32°	35°	32°	35°	32°	35°
Decay:								
At withdrawal...	0.6	0.7	1.6	2.3	0.3	1.3	2.4	4.8
Ten days later...	1.8	1.3	2.0	2.3	2.3	4.4	10.2	13.2

WINESAP.

Decay:								
At withdrawal...	0.1	0.2	0	0.2	0.3	1.2	0.5	0.7
Ten days later...	.3	.4	0	.3	.8	3.1	1.1	3.7

It will be noted that early in the storage season there is little difference in the amount of decay which develops in Winesap and

Rome Beauty stored at 32° and 35° F. Noticeable differences in appearance and texture were apparent in nearly all lots at this time, however. At the third and fourth withdrawals of these varieties the fruit stored at 35° showed considerably more decay than that stored at 32° F. In other words, fairly good keeping varieties may be held for some time at a temperature of 35° F. with practically as good results as far as loss from decay is concerned as if the fruit had been held at a lower temperature. As these varieties approach the end of their storage periods, however, the effect of the higher temperature is manifest, and the failure properly to retard the life activities of the fruit results in its premature death and decay. This is especially noticeable during the holding period after the fruit has been withdrawn from storage. The apples stored at 32° F. had enough reserve vitality to hold in good condition during this period, but the more advanced 35° F. fruit went down with comparative rapidity.

In Esopus (Spitzenberg) striking results are noted at the first two withdrawals and inspections. As the storage life of this variety is naturally shorter than that of Winesap and Rome Beauty, results of this kind are to be expected. Storage at 35° F. has materially shortened the holding period of the lots so treated, and this influence is manifested very early in the storage season.

The most favorable storage temperature, however, can not prevent the final, natural death of the fruit, and at the third and fourth withdrawals of Esopus (Spitzenberg) both lots are past the limit of successful storage, although the lots from 32° F. are still superior to those which have been stored at 35° F.

COMMON STORAGE.

During the seasons of 1912–13, 1913–14, and 1914–15 a limited number of boxes of apples were stored in well-constructed common storage houses at Hood River, Oreg., and at Payette, Idaho, while comparable lots were held in cold storage at 32° F. As the data obtained were limited, no attempt will be made to present them or to discuss the result in detail until corroborated by further investigation.

As might be expected, however, they indicate that a common storage house cooled by natural circulation only can not take the place of a cold-storage warehouse for long keeping of the fruit. This statement does not in any way belittle the value and utility of common storage houses, as they will always play an important part in the harvesting and storage of the apple crop. The fact that a house of this type can be constructed at the orchard or in conjunction with the local packing house with a much smaller outlay of capital than is required for the construction of a cold-storage warehouse is a

strong point in its favor. From the standpoint of a grower or shipper who wishes to hold his fruit for a few weeks or even a few months before placing it in cold storage or finally disposing of it, a common storage warehouse offers numerous advantages. If it is desired to ripen winter varieties, such as Winesap or Yellow Newtown, for an early market, they can probably be more satisfactorily handled in common than in cold storage. Furthermore, the operation of a house of this kind requires no technical knowledge.

The fact remains, however, that during the fall months it is usually difficult in many localities to obtain by natural cooling temperatures that are low enough to permit long storage. During the late fall and winter, however, a temperature very close to 32° F. can be maintained in most sections of the Northwest. The effect of storage of this kind is similar, therefore, in practice to that of a long delay before storage, although the conditions during this delay period are more favorable than the average. It was found, as might be expected, that common storage fruit compared with lots from the same orchards held at 32° F. was yellower, duller, and nearer the end of its storage life at all withdrawals and inspections than the fruit held at the lower temperature.

DETERIORATION AFTER WITHDRAWAL FROM STORAGE.

It is not only desirable to hold apples in storage with a minimum amount of loss, but of equal importance that this fruit remain in good condition for some time after it is withdrawn and placed on the market. In many instances apples withdrawn from cold storage are reshipped for considerable distances, and in all cases they are in the hands of the wholesaler, retailer, and consumer for several days, oftentimes weeks. Allowance should be made for the length of time it will probably take a particular lot to go into consumption and the temperature and other conditions to which it will probably be subjected. As a general rule, apples should be bright, firm, and not excessively yellowed when withdrawn from storage. In some varieties deterioration in quality will limit the length of time they can safely be allowed to remain in storage. After withdrawal the fruit, of course, should be held at the lowest temperature obtainable.

It has been very generally believed that apples withdrawn from a temperature of 32° F. break down very rapidly under normal outside temperatures and deteriorate faster under these conditions than fruit which has been held at a higher temperature. The experiments show that of two comparable lots, one from 32° F. and one from common storage, withdrawn from storage at the same time, the one from the lower temperature will hold up for a longer period

in good condition. In other words, the more successfully and promptly the ripening processes of an apple are retarded the longer it will remain in good condition in and out of storage. If, however, the fruit is allowed to remain in cold storage until overripe, it will naturally break down very rapidly when withdrawn.

In this connection attention is called to Table IV. It will be seen that the amount of decay which developed during the 10-day holding period after withdrawal from storage was in nearly all cases much greater in the fruit stored at 35° F. than in that from 32° F.

LOCAL VERSUS DISTANT STORAGE OF NORTHWESTERN APPLES.

There is considerable discussion as to whether storage in producing sections is preferable to storage of northwestern fruit in the Middle West and East. While there are good arguments in favor of both systems, at present local storage space is not available for as much as half of the normal apple production of these States. Even if there should ever come a time when adequate facilities for the home storage of the entire crop are available, it would probably be desirable to store a certain percentage of the crop nearer the consuming centers. It therefore seems practically certain that the growers of northwestern apples will utilize, at least for some time to come, both home and eastern storage.

Where apples are stored at points of production in the Northwest, full and due allowance should be made for the time required for shipment to eastern markets and for distribution to the consumers. In most cases it will not be practicable to hold any variety at producing points the full and normal storage period for the variety. Such practices will generally only result in very serious losses from deterioration and decay. Obviously, if a variety has already been held in storage for the maximum period during which it will normally remain in good condition, it can not successfully be transshipped several thousand miles and be delivered in good condition. The different varieties should be withdrawn from storage early enough before the end of their normal storage seasons to permit shipment and distribution while in good attractive condition.

In transferring from warehouse to car, care should be taken not to expose the fruit to much higher temperatures than that at which it was held. When shipped during extremely cold weather every precaution should be exercised to secure such equipment and to take such precautions as are practicable to protect the apples from freezing in transit. In the shipment of apples that have been held in storage for a considerable period the maintenance of uniformly low temperatures above freezing is of especial importance. The rate of development of scald decay and other storage troubles after withdrawal from

storage emphasizes strongly the need of maintaining uniformly low temperatures, consistent with safety from freezing, throughout all operations of handling and transportation to the retailer and consumer.

Practically all northwestern-grown apples that are forwarded to eastern markets for storage are shipped as soon as possible after the fruit has been harvested and packed without being placed in cold storage at or near the points of production.

The need of prompt cooling has been strongly emphasized in connection with immediate and delayed storage. It is very evident that whether stored near points of production or several thousand miles distant, the need of prompt and rapid cooling is exceedingly important. When stored near the point of production every effort should be made to get the fruit into the storage house promptly. When intended for eastern storage the apples should be shipped in refrigerator cars under refrigeration. They should be loaded into preiced cars as promptly as possible after harvesting. As the average cooling of a full load of tightly packed and wrapped apples in a refrigerator car is comparatively slow at best, the need of getting the fruit under refrigeration promptly is even greater than if they were going directly into storage. Precooling is an efficient means of securing prompt and rapid cooling and should be utilized wherever facilities are available. Promptness of cooling is essential to good keeping quality, whether effected through precooling or in the car in which the fruit is shipped while in transit.

THE RELATION OF ORCHARD PRACTICES TO SUCCESSFUL STORAGE.

While harvesting and handling methods, the promptness of storage, and storage temperatures are among the most important factors governing keeping quality in storage, the important relation of orchard practices to successful storage should not be overlooked. It has been noted previously that scald appears first and primarily on the uncolored portion of the apple. In this connection pruning is an important consideration. As it is desirable to procure high color, both from the standpoint of avoiding scald and increasing the market value of the fruit, it is of great importance that the pruning be sufficient to admit enough light to properly color the apple.

As scab and anthracnose are often very serious in storage it is important that proper spraying and pruning methods be followed in order to control these and other fungous diseases. The general good health and vigor of the trees should be maintained by proper cultural and orchard sanitation practices, for sickly trees can not be expected to produce good storage fruit.

RESPONSIBILITY AND INSPECTION.

The responsibility for the successful storage of apples obviously does not lie with the storage warehouseman alone. In fact, he has largely done his part if the apples are properly stored as soon as they reach the storage house in clean well-insulated rooms held at a uniform temperature of 31° to 32° F. where each grower's fruit of each variety can be examined occasionally and quickly withdrawn to meet the demands of the market.

As has been previously shown, the first responsibility lies with the growers and shippers, since cultural and handling methods largely determine the condition of the fruit when stored. Through his cultural and orchard sanitation practices the grower determines and is responsible for the inherent keeping quality of fruit and its freedom from fungous troubles. Through the care exercised in handling, the time of picking as related to maturity, and the promptness of cooling and storage, the growers and shippers largely determine the life and behavior of the fruit in storage.

As many factors influence the keeping quality of the different lots and as few lots even of the same variety possess the same keeping quality, occasional inspections of representative boxes of each variety from each grower are desirable. In this way the lots most advanced in maturity can in so far as possible be disposed of while still in good condition. The difficulties of making such inspections of all lots in storage are often great. Nevertheless, anyone familiar with the wide variation in keeping qualities of different lots of apples apparently identical at the time of storage will not seriously question the value of such inspection in connection with the disposal of storage holdings in the best merchantable condition.

COMPARATIVE KEEPING QUALITIES OF VARIETIES OF PACIFIC NORTHWESTERN APPLES.

In order to secure an accurate comparison of the keeping qualities of the more important promising fruit a great many varieties of fall and winter apples were tested in cold storage. These tests were made with lots from North Yakima, Wenatchee, and Spokane, Wash.; Hood River, Medford, and Milton and Freewater, Oreg.; Payette, Idaho; and other sections of the Pacific Northwest. The investigations were extended over a period of four years, during which time approximately 600 boxes of apples were used in these variety tests. All lots were held at a temperature of 31° to 32° F.

Table V gives the varieties on which the data are sufficient to base dependable conclusions. An attempt has been made in this table to arrange the varieties in the order of their keeping qualities. This is based on their market condition, texture, color, quality, flavor, and the amount of decay and skin blemish. It also includes the

average dates at which the experimental lots passed prime market condition, and their susceptibility to scald.

In the same connection the notes on the varieties, following the table, are of interest, as they include important factors in connection with the successful storage of each variety.

TABLE V.—*Comparative cold-storage keeping qualities of varieties of Pacific Northwestern apples.*

No.	Variety.	Average date experimental lots passed prime condition for market.	Susceptibility to scald.
1	Rainier	May or later	Practically free.
2	Hyde King	May	Very slight.
3	Arkansas Black	do	Do.
4	Winesap	Last of April	Slight to bad.
5	Yellow Newtown	do	Do.
6	Rome (Rome Beauty)	Middle of April	Do.
7	Northern Spy	do	Slight.
8	Missouri	do	Do.
9	Delicious	Last of March	Slight to bad.
10	York Imperial	First of March	Do.
11	Winter Banana	do	Slight.
12	White Pearmain	do	Slight to bad.
13	Ben Davis	do	Do.
14	Esopus (Spitzenberg)	Last of February	Very slight.
15	Gano and Black Ben	Middle of February	Bad.
16	Stayman Winesap	do	Do.
17	Salome		Slight.
18	Ortley	February	Slight to bad.
19	King David	First of February	Slight.
20	McIntosh	Middle of January	Do.
21	Tompkins King		Slight to bad.
22	Wagener		Bad.
23	Jonathan	First of January (very valuable)	Very slight.
24	Arkansas (Mammoth Black Twig)		Bad.
25	Grimes	Middle to last of December	Do.

NOTES ON THE KEEPING QUALITIES OF VARIETIES OF APPLES GROWN IN THE PACIFIC NORTHWEST.

RAINIER.—The keeping qualities of the Rainier apple are unsurpassed by those of any other variety of the Pacific Northwest that has yet come to the attention of the United States Department of Agriculure. Its ability to retain its firmness, brightness, and quality with almost no decay or skin blemish places it above even the Arkansas Black, Winesap, and Yellow Newtown. In 32° F. cold storage it keeps in prime condition into May or later, and instances are known where large numbers of boxes have been held in excellent condition into September of the year following their harvest.

The department's first record of the Rainier is from the farm of W. W. Scott, at North Yakima, Wash., where there is an orchard of what were wrongly called Hubbardston Pippins. No very accurate or dependable record could be found as to their true name and they were given the name Rainier. The Rainier is of medium size, with rich yellow ground color, mottled and washed with red, splashed and striped with dark red; oblong-conical, irregular, symmetrical, fairly uniform in shape; and of reasonably good quality.

HYDE KING.—The Hyde King possesses valuable cold-storage qualities. It is a large beautifully bluish yellow apple of unusual firmness, which it holds throughout its storage life. Little or no scald occurred in this variety. In the experimental storage lots it usually kept well into May in good marketable condition.

ARKANSAS BLACK.—The Arkansas Black, one of the most important commercial varieties of this section, is also one of the longer keeping varieties. Well-colored

and matured fruit remained in prime condition into May. Immaturely picked fruit scalds very badly and decays physiologically much sooner than fruit picked when properly matured.

WINESAP.—The Winesap is one of the most widely grown of the longer keeping varieties. When well colored and matured it kept with little or no decay into the latter part of April. As with most varieties, immature fruits scald badly, although this scald seldom results in physiological decay. In some localities the Winesap often water-cores, but when the water-core is slight the injury to the keeping quality is not as great as with most other varieties.

YELLOW NEWTOWN.—The excellent dessert and culinary qualities of the Yellow Newtown do much to make it a desirable cold-storage variety. It is very susceptible to scald if picked immaturely, and in some sections may develop a browning of the core, which sometimes lowers its market value. Scab is sometimes serious on this variety in storage. Its storage season is usually about the same as that of the Winesap.

ROME (ROME BEAUTY).—When picked at the proper maturity this variety is valuable for cold-storage purposes. However, if picked immaturely very severe scald usually develops in storage. Overmaturity is equally bad, resulting in serious decay. Scald on the Rome Beauty sometimes takes on the appearance of Jonathan spot and later spreads over larger portions of the surface, but more often it is of the common type. Its storage season varied greatly, depending principally on the time of harvesting and the delay between picking and storage, but it generally extended to the middle of April.

NORTHERN SPY (SPY).—On many sites the Northern Spy is very susceptible to bitter-pit, which is one of its worst storage troubles. Bitter-pit often does not make its appearance until some time after packing. The tender skin of this variety is easily broken, with the result that the loss from blue-mold decay may be high. It usually did not keep well after the middle of April.

MISSOURI.—In general the Missouri kept well, with little scald or other deterioration, beyond the middle of April. It has many desirable points as a storage variety.

DELICIOUS.—The Delicious is a better storage variety than its rather delicate appearance indicates. It usually holds its flavor fairly well and is not as seriously affected by scald as are most varieties. It seldom held up well beyond the last of March.

YORK IMPERIAL.—The York Imperial is not a high-quality storage variety, but it held up well until the middle of March. It scalds badly, especially after withdrawal from storage.

BANANA (WINTER BANANA).—When picked at the proper stage of maturity this variety has good keeping qualities. Apples picked when overmature will deteriorate rapidly in storage. Its season usually ended about the first of March.

WHITE PEARMAIN (WHITE WINTER PEARMAIN).—This variety has a high dessert quality which it maintains for a time in storage, but loses in late winter. It often scalds badly, and physiological decay soon follows. The storage season ended about the first of March.

BEN DAVIS.—Like most other varieties in storage, when picked immaturely the Ben Davis scalds badly. When well colored and picked at proper maturity the Ben Davis takes high rank as a storage variety, but its cold-storage keeping qualities do not appear to be as high as many believe. It usually did not keep in good condition beyond March 1.

ESOPUS (SPITZENBERG).—The Esopus retains a good flavor for most of the storage season, and when not picked overmaturely it is a good keeper. Its harvesting season is comparatively short, and fruit that is overmature when

picked soon decays. Esopus is exceptionally subject to attack by northwestern anthracnose even in storage. This is an important consideration when the fruit is grown in localities where this disease is prevalent. Generally this variety did not remain in good market condition past the latter part of February.

Gano.—The Gano and Black Ben (the Black Ben is probably but a strain of the Gano, and its storage-keeping quality is similar) are not as good storage apples as is often thought. Their color becomes unattractive, and they are subject to very bad scald. Apples of the variety that are not well matured and well colored should seldom be stored for any length of time. The Gano did not usually remain in the best condition past the middle of February.

Stayman (Stayman Winesap).—The high quality and firmness of the Stayman Winesap are retained in storage for some time, but unfortunately this variety is susceptible to extremely bad scald, which is soon followed by physiological decay. To guard against this the greatest care should be taken to store only fruit that is fully matured and well colored. Late picking is also dangerous in some localities, as water-core may develop. The Stayman Winesap passed good market condition about the middle of February.

Salome.—The keeping quality of the Salome was rather variable, averaging in general not quite as good as that of the Stayman Winesap. It remains unusually bright and attractive through the season, and occasional well-colored lots show excellent keeping quality.

Ortley.—For a short storage season the Ortley is often valuable. However, its susceptibility to scab, core browning, northwestern anthracnose, and scald are against its extensive use in cold storage. The scald often appears in small spots resembling Jonathan spot. The Ortley retains its flavor well for a time, but later becomes flat. Most of the Ortleys remained in good condition until after the first of February.

King David.—For short-season storage this variety is very good. When picked early enough to avoid water-core it can usually be held without serious deterioration somewhat longer than can Jonathan. Excessively early picking, however, encourages scald. It is probable that fruit picked before reaching a total dark red is as attractive as the darker and overmature fruit; and as the storage keeping quality of this earlier picked fruit is unquestionably better, the earlier picking is advised. In general the picking dates should be somewhat before those of Jonathan. King Davids picked under these conditions kept well until the first of February or later.

McIntosh.—For short-time storage high-grade McIntosh apples are valuable. Their high dessert quality and comparative freedom from scald are in their favor. In late winter they lose in flavor, and physiological decay soon follows. They remained in good condition until the middle of January.

Tompkins King.—As the Tompkins King water-cores and scalds badly, it is seldom a good storage variety. In cases where well-matured and well-colored fruit is obtained without water-core, successful storage may result, but otherwise this variety is not to be depended on in storage.

Wagener.—Of the varieties grown in the Northwest, the Wagener is one of the most susceptible to scald. The scald is followed quickly by physiological decay. When well-colored mature fruit is obtained it can be held successfully for a considerable period, as the scald may then be practically eliminated. The average Wageners did not keep much past the middle of January.

Jonathan.—The Jonathan varies more in its keeping quality than does almost any other variety. In general the earlier harvested fruit keeps better, though very early harvesting results in shriveling and poor flavor. Jonathan spot and soft scald are its greatest enemies in storage. Both are more serious on this

variety than on any other that is extensively grown. As delay between picking and storage almost invariably results in both decay and Jonathan spot, immediate storage is particularly important with the Jonathans. They usually passed their best commercial condition the latter part of December.

GRIMES (GRIMES GOLDEN).—Grimes has a short storage season. It holds its flavor fairly well, but ripens quickly and is particularly susceptible to scald. In cold storage it should seldom be held later than the middle or latter part of December.

SUMMARY.

During the seasons 1911–12 to 1914–15, inclusive, extensive investigations were conducted by the United States Department of Agriculture to determine those factors which are of the greatest importance to the successful storage of the apples of the Pacific Northwest. For this purpose apples were secured from the various more important apple-growing sections of Washington, Oregon, Idaho, and Montana.

The experiments conducted in 32° F. storage showed—

A wide range in the cold-storage keeping qualities of various varieties, depending upon the decay, skin blemish, texture changes, etc., which they develop.

That a 2-weeks' delay between the picking and storage of apples often greatly reduces their life in storage through more rapid ripening and the development of scald, Jonathan spot, scab, and decay.

That a 32° F. temperature will hold apples longer and in better condition than will a 35° F. temperature, the difference in favor of the former increasing with the time in storage.

Immature picking results in severe scald and early decay of apples in storage.

The storage of overmature apples is an equally bad or worse practice than the storage of immature apples, resulting in more rapid deterioration than with those picked and stored at proper maturity.

Well-colored portions of the skin seldom, if ever, develop scald.

Carelessness in handling is responsible for considerable decay of apples in storage, and freedom from bruises and skin abrasions is fundamental to successful storage.

Apples from orchards badly infected with northwestern anthracnose are likely to decay early in their storage life.

Apples in cold storage should be carefully watched and inspected in order that they may be disposed of while in good condition.

In conclusion, it is pointed out that successful cold storage of apples is as much the result of the treatment they receive before being placed in cold storage as of the conditions and temperatures under which they are held in storage. The responsibility rests as much with the producer and handling organizations as with the cold-storage warehousemen.

OTHER PUBLICATIONS OF THE UNITED STATES DEPARTMENT OF AGRICULTURE RELATING TO APPLES.

AVAILABLE FOR FREE DISTRIBUTION.

The Profitable Management of the Small Apple Orchard on the General Farm. (Farmer's Bulletin 491.)

The More Important Insect and Fungous Enemies of the Fruit and Foliage of the Apple. (Farmers' Bulletin 492.)

Apple-Tree Tent Caterpillar. (Farmers' Bulletin 662.)

Roundheaded Apple-Tree Borer. (Farmers' Bulletin 675.)

Management of Common Storage Houses for Apples in the Pacific Northwest. (Farmers' Bulletin 852.)

Apple Powdery Mildew and Its Control in the Pajaro Valley. (Department Bulletin 120.)

Apple Market Investigations, 1914–15. (Department Bulletin 302.)

The Cost of Producing Apples in Wenatchee Valley, Wash. (Department Bulletin 446.)

The Woolly Apple Aphis. (Secretary's Report 101.)

FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS, GOVERNMENT PRINTING OFFICE, WASHINGTON, D. C.

The Apple and How to Grow It. (Farmers' Bulletin 113.) Price, 5 cents.

Apples: Production Estimates and Important Commercial Districts and Varieties. (Department Bulletin 485.) Price, 10 cents.

The Control of Apple Bitter-Rot. (Bureau of Plant Industry Bulletin 93.) Price, 10 cents.

Apple Leaf-Spot Caused by Sphaeropsis Malorum. (Bureau of Plant Industry Bulletin 121, part 5.) Price, 5 cents.

The Substitution of Lime-Sulphur Preparations for Bordeaux Mixture in the Treatment of Apple Diseases. (Bureau of Plant Industry Circular 54.) Price, 5 cents.

Experiments on the Apple with Some New and Little-Known Fungicides. (Bureau of Plant Industry Circular 58.) Price, 5 cents.

Studies on Apples. (Chemistry Bulletin 94.) Price, 20 cents.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
15 CENTS PER COPY

▽